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REPORT OF ENVIRONMENTAL SAMPLING
UNIMAR YARD 1 DRY DOCK FACILITY
LAKE UNION
SEATTLE, WASHINGTON
FOR
UNITED MARINE INTERNATIONAL, INC.

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INTRODUCTION

The results of our environmental sampling investigation of the bottom sediments and water at the Lake Union Yard 1 Dry Dock facility are presented in this report. The Yard 1 facility is located along the north shore of Lake Union in Seattle, Washington. The UNIMAR (Unimar International, Inc. and United Marine Shipbuilding, Inc.) facility was formerly owned and operated by WFI Industries, Inc. and MPE (Marine Power and Equipment Company, Inc). The facility has been operated by UNIMAR and it's predecessors since 1967. Four to six dry dock facilities of various capacities have been in operation at the site since the mid-1950s. The two largest dry docks at the site reportedly began operations between 1979 and 1982. Four dry docks were operated at the Yard 1 facility (Figure 1) during the field sampling program. Three dry docks (#2, #9 and #6) are presently operated at the Yard 1 Facility (dry dock #8 has been removed). The dry docks are used for ship construction and repair, which usually include sandblasting and painting operations. Sandblasting grit and paint residue have accumulated on the bottom of Lake Union in and near the dry docks as a result of past operations and practices. Various types of sandblasting materials (river sand, silica sand and sandblasting grit) have been used at the facility during past operations.

PREVIOUS ON-SITE INVESTIGATIONS

The EPA (Environmental Protection Agency) collected 137 bottom sediment cores at the Yard 1 facility to estimate the extent of the sandblasting materials on the lake bottom. Sediment core logs, analytical results and bioassay results are presented in EPA's draft report "Marine Power and Equipment, Technical Status Report," dated March 3, 1987.

Additional sampling (32 sediment cores) and analysis of the bottom sediment were undertaken by MPE to further characterize the bottom sediments. The sediment core logs and analytical results for the MPE

sampling are presented in GeoEngineers' "Report of Environmental Consultation, Bottom Sediment Conditions, Marine Power and Equipment, Yard 1 Dry Dock Facility, Seattle, Washington," dated June 1, 1988.

A previous GeoEngineers analysis of sandblasting material estimated approximately 5,300 cubic yards of potentially contaminated sediment on the lake bottom at the Yard 1 facility. The estimate of sandblasting material volume has been updated to approximately 6,500 cubic yards in-place. The approximate distribution of the sandblasting material is presented in Figure 2. This estimate has been compiled from data collected during past studies conducted by the EPA and GeoEngineers and has been updated to include the January 1991 sediment core data.

INDUSTRIAL IMPACTS IN LAKE UNION

The 1916 completion of the Montlake Channel and Hiram M. Chittenden Locks provided navigable passage from Lake Washington through Lake Union to Puget Sound and accelerated the rise of commercial and maritime industries along the shoreline. A report completed for the Washington State Pollution Commission in 1943 listed 45 industries along the shoreline of the Lake Union and the Lake Washington Ship Canal. Twenty of the 45 industries were listed as sources of pollution, not including the marinas and boat yards. The industries included 10 marine shops and metal foundries; 10 lumber and plywood mills; 12 fuel and oil storage and service facilities shops; eight sand, gravel, concrete and asphalt companies; the Seattle City Light Power Plant; and Gas Works Park (formerly Seattle Gas Plant), which was listed as the worst source of lake water pollution. Numerous studies have been completed for characterizing the extent of contamination at Gas Works Park, including the bottom sediments of Lake Union. A general summary of studies performed at Gas Works Park is presented at the end of this report.

A 1977 report, "A Baseline Study of the Water Quality, Sediments, and Biota of Lake Union," by Richard Tomlinson and others completed for METRO (Municipality of Metropolitan Seattle) describes the environmental impacts to Lake Union. Prior to 1960, raw sewage and stormwater outfalls discharged polluted water directly to Lake Union through numerous combined stormwater and sewage outfalls that often became overloaded with flow during rainfall events. Most of these outfalls were upgraded with the creation of Metro in the early 1960s, but 19 were still reported in use as of 1986. These

combined outfalls discharged a total of more than 450 million gallons of raw sewage and stormwater into Lake Union annually. The poor water quality emanating from these outfalls is a result of pollution associated with urban runoff (houses, city streets, highways and paved areas), accidental spills, improper disposal practices and previously unregulated material storage and handling practices. The pollutants detected in samples collected from these combined outfalls include heavy metals, PCBs (polychlorinated biphenyls), oil and grease, nitrate, phosphate, coliform bacteria and pesticides.

It has been suggested that ground water discharging from upland contaminant sources such as Gas Works Park may be contributing pollutant loadings to the sediments on the lake bottom. It was reported in the METRO report that 68 percent of the total lead in Lake Union sediments enters the lake via atmospheric fallout and rainfall.

SCOPE OF WORK

The purpose of this study is to further characterize the chemical characteristics and toxicity of bottom sediments at the UNIMAR Yard 1 Dry Dock facility. Samples were collected from the bottom sediments and subsurface waters of Lake Washington, Lake Union and the Yard 1 Dry Dock facility. These samples were tested for the chemical constituents and biological test methods as described in the QA/QC plan (FishPro, QA/QC Plan for Sediment and Water Sampling at UNIMAR Yard 1 Dry Dock Facility, Seattle Washington, August 1990) and evaluated to determine the environmental risk associated with the sandblasting materials. The scope of services completed during this investigation includes the following:

1. Collect sediment core samples from nine sampling stations located in Lake Union, Lake Washington and the Yard 1 Dry Dock facility. Collect one duplicate sediment sample at a random location within the Yard 1 Dry Dock facility.
2. Collect two horizontal discrete depth water samples from locations in Lake Union (one background sample and one site-specific sample) and collect one duplicate sample at the sample location within the Yard 1 Dry Dock facility.
3. Collect rinsewater blanks from the sampling equipment prior to start of sampling and between sampling locations to document sample equipment decontamination procedures.

4. Submit the water and sediment core samples, along with all appropriate chain-of-custody documentation, to an analytical laboratory for testing.
5. Test sediment and water samples for the analyses specified in the QA/QC plan.
6. Evaluate and characterize the toxicity of the sediments based on the data compiled from the analytical testing results.
7. Combine the results of the chemical analyses with the bioassay and benthic survey to determine the environmental significance of the sediment characteristics.
8. Address the conceptual remedial plans with regard to corrective action, no action, and environmental concerns.

The chemical analytical results were evaluated based on background data compiled from the Lake Union and Lake Washington sediment samples, PSDDA (Puget Sound Dredge Disposal Analysis) guidelines, and evolving fresh water sediment regulations. The sediment core sampling, equipment decontamination, and field blank sample procedures are presented in Appendix A. The sediment core logs are presented in Appendix B. The analytical testing results are presented in Appendix C. A copy of the analytical testing method used for the analysis of tributyltin is presented in Appendix D.

FIELD STUDIES

SEDIMENT SAMPLING

A total of 42 samples from nine sediment core stations were sampled with a Shelby Tube (5-foot-long stainless steel tube that was hand-driven into the sediment by a SCUBA diver) and a Van Veen sampler to evaluate the toxicity and chemical characteristics associated with the lake bottom sediments. Two to 12 discrete sediment samples were collected from each core station according to the sample intervals specified in the QA/QC plan. The sediment samples were collected in intervals ranging between 0.3 feet and 4.7 feet. Sediment stations 1 through 7 are located at the Yard 1 Dry Dock facility (Figures 1 and 2) and stations 8 and 9 are located in Lake Union (Figure 3) and Lake Washington (Figure 4), respectively. Duplicate sediment sample 11 was collected at station 6. A description summary of the sediment sampling procedures are presented in Appendix A.

WATER SAMPLING

Two discrete water samples were collected with a horizontal Beta sampler 1 foot above the lake bottom mudline at stations 2 (sample 2A) and 8 (sample 8A). In addition, duplicate water sample 12 was collected at station 2. A total of six rinsewater samples were collected from the Shelby Tube, Van Veen and Beta samplers prior to the start of sampling and at one sampling station. Presampling rinsewater blanks were collected for the Shelby Tube (10A) and the Van Veen (10C) at station 9 and for the Beta sampler (10E) at station 8. Sampling rinsewater blanks were collected for the Shelby Tube (10B), Van Veen (10D) and Beta samplers (10F) during sampling at stations 6 and 7.

Two of the sediment samples (2C and 8C) were partitioned into separate interstitial water and sediment samples by the analytical laboratory.

DEVIATIONS FROM PROPOSED SAMPLING PLAN

SEDIMENT SAMPLING

The deviations from the proposed QA/QC plan for the sediment sampling include relocating sediment sampling stations 1, 2, 4, 6, 7, and 9, and accepting less than a full sample core at station 9.

Sediment sampling station 1 was relocated approximately 30 feet to the south to provide acceptable recovery for the Van Veen and Shelby Tube samplers. The proposed station 1 had numerous pieces of debris that made obtaining a representative sample in the Van Veen impossible. The Shelby Tube repeatedly encountered refusal at a depth of approximately 1.5 feet and could not be driven to the required depth.

Sediment sampling station 2 was relocated approximately 20 feet to the west to allow better access for sampling with the Van Veen from the sampling platform (floating crane barge). The proposed station was located in an area with limited working area and difficult access because of the close proximity of dry dock 3 and a nearby vessel.

Sediment sampling station 4 was relocated approximately 25 feet to the west to allow the sampling platform to be docked alongside dry dock 6. The relocation allowed for better accessibility for the diver and the Van Veen sampler.

Sediment sampling stations 6 and 7 were relocated 25 feet and 15 feet, respectively, closer to the eastern shoreline bulkhead because of the positioning of the sampling platform.

Sediment sampling station 9 was relocated to the north end of Lake Washington to provide for a more representative background sample location. The maximum length of the sediment core recovered at station 9 was 2.6 feet after three cores recoveries of 2.5 feet were considered unacceptable. This length was less than the accepted criterion of 3.5 feet for the core sample recovery. The core was repeatedly driven to the 5-foot depth, but the full length of the core could not be recovered.

WATER SAMPLING

Duplicate water sample 12 was not collected immediately after water sample 2A was collected. Water sample 2A was collected prior to sampling the sediments with the Van Veen and Shelby Tube samplers. The duplicate water sample was collected at station 2 four days after the sediment sampling was performed.

ANALYTICAL TESTING METHODS

SUMMARY OF ANALYTICAL METHODS

Forty-two sediment samples were analyzed by ATI (Analytical Technologies, Inc.) of Renton, Washington, for various analytes including metals, semivolatile organic compounds (BNAs [base/neutral acid extractables] and PAHs [polynuclear aromatic hydrocarbons]), TPH (total petroleum hydrocarbons), PCBs (polychlorinated biphenyls) and moisture. Eleven of the 42 sediment samples were tested by TCLP (toxicity characteristic leaching procedure) for metals to evaluate the leaching potential of metals from the sediments. The laboratory analytical methods are presented on pages 2 and 3 at the front of each section of the certified analytical reports in Appendix C.

Three discrete water samples were tested by ATI for total metals and hardness and were submitted to their subcontracted laboratory (Tox Scan Inc., Watsonville, California) for analysis of butyltin species, in particular, TBT (tributyltin). Two sediment samples were centrifuged to separate the interstitial water from the sediment. The water samples were later analyzed for total metals and TBT. The laboratory methods for the water analyses are presented on pages 2 and 3 at the front of each section of the certified analytical reports in Appendix C. A complete description

of the laboratory method used for analyzing TBT, "Measurements of Butyltin Species in Sediments by n-Pentyl Derivation with (GC/MS) Gas Chromatography/Mass Spectrometry," is presented in Appendix D.

DEVIATIONS FROM THE PROPOSED WORK PLAN FOR SAMPLE ANALYSES

Two sets of sediment samples, 1B and 1C, were collected from station 1 on separate days and recorded on separate chain-of-custody sheets (lab IDs 9101-191-11 and -12, and 9101-203-1 and -2). The first set of samples was not analyzed because of insufficient core recovery. The precise sediment core sample interval for the first set of samples was questionable because a rock had blocked the core barrel. The second set of samples collected from station 1 was submitted for analyses. Sample 1C of this set was mistakenly recorded on the second chain-of-custody sheet; therefore, this sample was analyzed for PCBs and not PAHs. This error was not discovered until after the holding times expired.

Sediment sample 8D was not analyzed for the proposed list of analyses specified in the QA/QC plan because the sample quantity was insufficient. Sample 8D was analyzed only for the metals on the metals screen list in the QA/QC plan. Sediment sample 8C was analyzed for the full suite of testing as a replacement for 8D.

Sample 8C was centrifuged in the laboratory to separate the interstitial water from the sediment and recorded on page 2 of the chain-of-custody sheet as samples 8C water (lab ID 9101-167-15) and 8C sediment (lab ID 9101-167-16). The sediment portion of sample 8C was analyzed for the analyses specified for 8D, including TPH, PAHs and BNAs, PCBs, total metals and TCLP metals. The interstitial water portion of sample 8C was analyzed for total metals and TBT.

Sample 8F was not analyzed for PAHs because the sample quantity was insufficient. Sample 8F was analyzed for TPH and metals.

The detection limits specified in the final QA/QC plan for copper and silver (0.002 mg/l) were not met by the laboratory because of a communications error in reporting the required detection limits to the laboratory. It was not possible to reanalyze the water samples because the samples were disposed of before this error was discovered.

DEVIATIONS FROM THE PROPOSED WORK PLAN FOR ANALYTICAL TESTING METHODS

Three of the proposed analytical laboratory test methods (hardness, EP Toxicity and TBT) were replaced with alternative or updated methods

during the investigation. The proposed analytical test for hardness (EPA Method 130.1), which is performed by automatic titration, was replaced by EPA Method 130.2, which is performed by manual titration. The proposed leaching procedure for metals analysis, EP toxicity was replaced by the new TCLP (toxicity characteristic leaching procedure) for metals. These two replacement procedures were approved by the EPA before beginning the study. The proposed analytical method for TBT analysis by Atomic Absorption/Hydride was replaced with an updated method for TBT analysis, "Measurements of Butyltin Species in Sediments by n-Pentyl Derivation with GC/MS." The request for changing this method was documented in the January 17, 1991 letter to the EPA from GeoEngineers. Verbal approval for the updated TBT analytical method was granted in the field during a site visit by the EPA.

The detection limits specified in the final draft QA/QC plan for silver and copper (0.002 mg/l) in water samples were not met by the analytical laboratory because of a communications error in reporting the final required detection limits to the laboratory.

SAMPLE INTEGRITY

All samples were immediately placed on ice upon collection, placed in insulated shipping containers, and delivered to the laboratory with chain-of-custody seals intact and containing all completed chain-of-custody paperwork.

Samples 1B through 1H, 3A and 3B, sampled on Friday, January 25, 1991, arrived at the laboratory on Monday, January 28, 1991 with unfrozen ice packs (lab ID 9101-203). This shipping container was sealed with fresh ice packs on Friday evening, but did not arrive at the laboratory until Monday morning with the COC seals intact. All other samples arrived at the laboratory cold and intact.

QA/QC SAMPLE VALIDATION

Overall, the QA/QC data indicate that the accuracy and reproducibility of the samples were acceptable. All soil and water samples were extracted and analyzed within the recommended holding times with the exception of mercury, which was tested after the 28-day holding time during the TCLP metals analyses. The TCLP testing procedures specified in the QA/QC plan required the samples to be air-dried 60 days before extraction.

Low concentrations of copper and zinc were noted in the sediment sample reagent blanks for two of the batch analyses. These low levels do not represent a significant deviation from the recommended QA/QC procedures. No contaminants were reported in the water sample reagent blanks.

There were some general matrix interference problems noted in a few of the analytical batches, which were indicated by percent recoveries that were out of the control limits for mercury and zinc.

The QA/QC data for the PCB analyses were well within all acceptable limits for surrogate recoveries and no contamination was detected in the reagent blanks. The detection limits for sediment samples for stations 6 and 7 were elevated as a result of the significant levels of contamination present in the matrix.

The QA/QC data for the TPH analyses were within acceptable limits and no contamination was detected in the reagent blank samples.

The QA/QC data for the PAH analyses were within acceptable limits for the surrogate recoveries and no contamination was reported in the reagent blank samples. The QA/QC data for the BNA analyses were generally within acceptable limits. The accuracy of EPA Methods 8270 and 8310 was demonstrated in sample 8C, which was analyzed by both methods and attained similar results. Surrogate recoveries were generally within acceptable limits. Tentatively identified compounds were reported at very low concentrations in some of the reagent blanks.

The QA/QC data for the TCLP metals analyses were within acceptable limits and no contamination was reported in the reagent blank.

A total of six field rinseate samples were collected prior to the first sampling attempts (10A, 10C and 10E) and during the field study (10B, 10D and 10F) to confirm decontamination procedures. The results of the analytical testing for the equipment blanks are presented in each analytical summary section.

SUMMARY OF ANALYTICAL TESTING RESULTS--SEDIMENT SAMPLES

METALS

Quantification of metals in the sediment samples was performed by analyzing the samples for either total metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) or the metals on the metals screen list (cadmium, copper, lead, and zinc). A summary of the metals analyses for sediment samples is presented in Table 1.

The following sections present the general trends in the sediment concentrations of the background samples compared to the on-site samples. Duplicate sample 6A, designated sample 11, is included in the evaluation but will not be referenced unless a significant difference is noted between the two samples.

Arsenic:

Background Sampling Stations 9 and 8 - Arsenic was detected in background Lake Washington sediment samples 9A and 9B at concentrations of 8.9 mg/kg (milligrams per kilogram) and 2.3 mg/kg, respectively. The arsenic concentrations detected in background Lake Union sediment samples 8B (71 mg/kg) and 8C (24 mg/kg) were approximately nine and ten times greater than the concentrations found in Lake Washington for similar sampling intervals.

Sampling Stations 1 Through 7 - Arsenic was detected in the sediment samples from stations 1 through 7 at concentrations between 150 mg/kg and 3,100 mg/kg in the shallow interval (0 to 0.3 feet) (Figure 5). These concentrations are significantly greater than background concentrations. Arsenic detected in the sediment samples in the deep interval (0.3 to 5.0 feet) at stations 3 through 7 ranged from 26 mg/kg to 180 mg/kg (Figure 6), which are generally greater than the background concentrations. The highest arsenic concentrations (greater than 1,800 mg/kg) were detected at stations 1, 2, and 4.

Barium:

Background Sampling Stations 9 and 8 - Barium was detected in background sediment samples 9A and 9B at concentrations of 110 mg/kg and 51 mg/kg, respectively. Barium was detected in the background Lake Union sediment samples at generally similar concentrations of 92 mg/kg in both 8B and 8C.

Sampling Stations 1 Through 7 - Barium was detected in the sediment samples from stations 1 through 7 at concentrations between 32 mg/kg and 380 mg/kg. The highest barium concentrations (greater than 210 mg/kg) were generally detected at stations 1, 2 and 4. The concentrations detected from the other stations were generally less than two times the background results.

Cadmium:

Background Sampling Stations 9 and 8 - Cadmium was not detected in the background sediment samples at station 9. Cadmium was detected in the background sediment samples from station 8 at concentrations generally between 2 mg/kg and 3.6 mg/kg. However, 12 mg/kg cadmium was detected in 8M, which is from the 4.5 to 4.8 feet interval. The high concentration detected in 8M shows the possible background range of cadmium concentrations present in Lake Union.

Sampling Stations 1 Through 7 - Cadmium was generally detected in the sediment samples from the stations 1 through 7 at concentrations ranging from 4.4 mg/kg to 27 mg/kg for the shallow interval (Figure 7). Most of the samples resulted in cadmium concentrations greater than the background concentrations. The cadmium concentrations in the shallow interval were generally about two times greater than the concentrations in the deeper interval (Figure 8).

Chromium:

Background Sampling Stations 9 and 8 - Chromium was detected in background sediment samples 9A and 9B at concentrations of 39 mg/kg and 32 mg/kg, respectively. Chromium was detected in background sediment samples 8B and 8C at similar concentrations of 47 mg/kg and 32 mg/kg, respectively.

Sampling Stations 1 Through 7 - Chromium was detected in the sediment samples from stations 1 through 7 at concentrations generally ranging from 18 mg/kg to 89 mg/kg. However, a chromium concentration of 230 mg/kg was detected in sample 2C. Most of the sample results were 1.5 to 2 times greater than the background results. The deeper interval concentrations are generally similar to or slightly greater than the background concentrations.

Copper:

Background Sampling Stations 9 and 8 - Copper was detected in background sediment samples 9A and 9B at concentrations of 38 mg/kg and 15 mg/kg, respectively. The copper concentrations detected in background sediment samples 8B (170 mg/kg) and 8C (94 mg/kg) were approximately four and six times the concentrations detected in samples from background station 9 for similar depth intervals. Copper was detected in the discrete

background sediment samples from station 8 at concentrations generally between of 12 mg/kg and 180 mg/kg, with a significant decrease (less than 39 mg/kg) below the 3.0- to 3.5-foot interval.

Sampling Stations 1 Through 7 - Copper was detected in the sediment samples from stations 1 through 7 at concentrations between 230 mg/kg and 5,900 mg/kg in the shallow interval (Figure 9). These concentrations are significantly greater than background concentrations (9A and 8B). Copper was generally detected at concentrations exceeding background concentrations in sediments at stations 3B through 7B, with values between 89 mg/kg and 252 mg/kg in the deep interval (Figure 10). The highest copper concentrations (greater than 1,200 mg/kg) were detected in samples from stations 1, 2, 4 and 6. The copper concentrations detected in the sediment samples from stations 1 and 2 decreased significantly (to less than 100 mg/kg) below the 3.0-foot (1G) and 4.0-foot (2I) discrete sample depths.

Lead:

Background Sampling Stations 9 and 8 - Lead was detected in background sediment sample 9A at a concentrations of 68 mg/kg and was not detected in sample 9B. The lead concentrations detected in background sediment samples 8B (250 mg/kg) and 8C (130 mg/kg) were approximately four to greater than ten times the concentrations present at background station 9 for similar depth intervals. Lead was detected in the discrete background sediment samples from station 8 at concentrations generally between less than 40 mg/kg and 350 mg/kg, with an apparent decrease (to less than 50 mg/kg) below the 3.0- to 3.5-foot interval.

Sampling Stations 1 Through 7: Lead was detected in the sediment samples from stations 1 through 7 at concentrations between 210 mg/kg and 2,900 mg/kg in the shallow interval (Figure 11). These concentrations are significantly greater than background concentrations (9A and 8B). Lead was generally detected at concentrations greater than background concentrations in sediment samples 3B through 7B, with values between 97 mg/kg to 230 mg/kg from the deep interval (Figure 12). The highest lead concentrations (greater than 1,700 mg/kg) were detected at stations 1, 2, and 4. The lead concentrations detected in the sediment samples from stations 1 and 2 decreased significantly (to less than 100 mg/kg) below the 3.0-foot (1G) and 4.0-foot (2I) discrete sample depths.

Mercury:

Background Sampling Stations 9 and 8 - Mercury was not detected in the background sediment samples at station 9. Mercury was detected in background sediment samples 8B and 8C at concentrations of 1.53 mg/kg and 1.18 mg/kg, respectively. The station 8 sample results will be used as background concentrations for Lake Union.

Sampling Stations 1 Through 7 - Mercury either was not detected or was detected in sediment samples from stations 1 through 7 at concentrations ranging from 0.80 mg/kg to 1.52 mg/kg. The sample results show no significant difference compared to the Lake Union background concentrations for mercury.

Nickel:

Background Sampling Stations 9 and 8 - Nickel was detected in background sediment samples 9A and 9B at concentrations of 41 mg/kg and 31 mg/kg, respectively. Nickel was detected in the background sediments samples from 8B and 8C at slightly greater concentrations of 48 mg/kg and 49 mg/kg, respectively.

Sampling Stations 1 Through 7 - Nickel was generally detected in sediment samples from stations 1 through 7 at concentrations ranging from 13 mg/kg to 78 mg/kg; the greatest concentration (130 mg/kg) was detected in sample 2C. Most of the sample results generally were less than 1.5 times the background results. The deeper interval sample concentrations were generally slightly greater than the background concentrations with the exception of the samples from station 3, which were less than 0.5 times the background concentrations.

Selenium:

Sampling Stations 1 Through 9 - Selenium was not detected in the background sediment samples or in the Yard 1 Dry Dock samples.

Silver:

Sampling Stations 1 Through 9 - Silver was not detected in the background sediment samples but was detected at concentrations of 2 mg/kg to 4.7 mg/kg in sediment samples from stations 1 through 4.

Zinc:

Background Sampling Stations 9 and 8 - Zinc was detected in background sediment samples 9A and 9B at concentrations of 120 mg/kg and 44 mg/kg, respectively. The zinc concentrations detected in background sediment

samples 8B (340 mg/kg) and 8C (260 mg/kg) were approximately three to six times greater than the concentrations present in samples from background station 9 at similar depth intervals. Zinc was detected in the discrete background sediment samples from station 8 at concentrations between 39 mg/kg and 430 mg/kg, with an apparent decrease (to less than 100 mg/kg) below the 3.0- to 3.5-foot interval.

Sampling Stations 1 Through 7 - Zinc was generally detected in the sediment samples from stations 1 through 7 at concentrations significantly greater than background concentrations (9A and 8B) with values between 660 mg/kg and 13,000 mg/kg in the shallow interval (Figure 13). Zinc was generally detected at concentrations between 210 mg/kg and 620 mg/kg from the deep interval (Figure 14); these concentrations are greater than background concentrations in samples 3B through 7B. The highest zinc concentrations (greater than 4,000 mg/kg) were detected in samples from stations 1, 2 and 4. The zinc concentrations detected in the sediment samples from stations 1 and 2 decreased significantly (to less than 190 mg/kg) below the 3.0-foot (1G) and 4.0-foot (2I) discrete sample depths.

SEMIVOLATILE ORGANIC COMPOUNDS

The quantification of semivolatile organic compounds in the sediment samples was performed by analyzing the samples by EPA Methods 8310 (PAHs) and 8270 (BNAs). The data summarized in Table 2 were compiled from the entire list of semivolatile analyses. Table 2 includes only the constituents detected and the method detection limits. Estimated values are included in Table 2 but tentatively identified compounds are not included, because these compounds have no intrinsic value in our analysis. Tentatively identified compounds (detected by the mass spectrometer) have molecular spectral patterns that are similar in composition to one or more compounds, thus individual compounds cannot be distinguished and are placed into molecular categories (compound classes) during the computer search.

The majority of the semivolatile organic compounds results fall into two main categories: LPAHs (low molecular weight polynuclear aromatic hydrocarbons) including acenaphthene, acenaphthylene, fluorene, naphthalene, phenanthrene, and 2-methylnaphthalene; and HPAHs (high molecular weight polynuclear aromatic hydrocarbons) including anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)-pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)-

pyrene, and pyrene. Two additional compounds presented in Table 2 under the miscellaneous category include bis(2-ethylhexyl)phthalate and dibenzofuran. The following sections briefly summarize and compare the general trends of the background and on-site data results for the LPAHs, HPAHs and miscellaneous compounds.

General Summary LPAHs, HPAHs and Miscellaneous Compounds:

Background Sampling Stations 9 and 8 - Semivolatile organic compounds were not detected in background sediment sample 9A greater than the method detection limit (0.68 mg/kg). The total concentrations (sum) of semivolatile organic compounds in the sediment samples from background station 8 are approximately 45 mg/kg for LPAHs and 211 mg/kg for HPAHs for the shallow interval and approximately 5 mg/kg for LPAHs and 41 mg/kg for HPAHs for the 0.3-foot to 2.0-foot interval. The Lake Union background results represent a significant difference in concentrations compared to the Lake Washington background results. Miscellaneous compounds were not detected in sediments at station 8. No comparisons will be made with the miscellaneous compounds.

Sampling Stations 1 Through 7 - The total LPAHs detected in sediment samples from stations 2, and 4 through 7 were generally at concentrations greater than 55 mg/kg, which is significantly greater than the total background concentrations from 8B (Figures 15 and 16). The total LPAH concentrations in these sediment samples range from approximately 56 mg/kg (5A) to 349 mg/kg (6A) for the shallow interval, while the results from the deeper interval range from 13 mg/kg (5B) to 384 mg/kg (6B). The sediment sample results for stations 1 and 3 indicate that the detected total LPAH concentrations are much less than the total background concentration for 8B (46 mg/kg) in the shallow interval, with approximate concentrations between 16 mg/kg to 20 mg/kg. However, the total LPAH concentrations for 3B (20 mg/kg) was greater (21 mg/kg) than background sample 8C (5 mg/kg) in the deeper interval. Stations 6 and 7 have the highest overall LPAH sediment contamination while stations 1 and 3 have the lowest. Stations 2, 4 and 5 generally fall within the low to middle range of overall LPAH concentrations.

The total HPAH concentrations detected in the samples at stations 1 through 7 generally are either less than 76 mg/kg or greater than 145 mg/kg (Figures 17 and 18). Total HPAHs were detected in the greatest concentrations at stations 4 through 7, with ranges of approximately 145 mg/kg to

173 mg/kg at stations 4, 6 and 7 for both sample intervals, and approximately 302 mg/kg and 88 mg/kg for the shallow and deeper intervals at station 5. Total HPAH concentrations were the lowest in the sediment samples from stations 1 through 3 (between 26 mg/kg and 76 mg/kg for both intervals). Overall, however, significant HPAH concentrations were detected in the background and on-site samples.

A general evaluation of the semivolatile organic compounds data shows that sediments at stations 1 through 3 have the lowest LPAH and HPAH concentrations, while the highest concentrations are present at stations 4 through 7 and background station 8.

No general trends are evident in the sediment samples for the two miscellaneous semivolatile compounds. Bis(2-ethylhexyl)phthalate was detected in samples from stations 1 through 4 at concentrations between 1.8 mg/kg (estimated value) and 10 mg/kg. Dibenzofuran was detected in samples from stations 1, 2, 4 and 6 at concentrations between 1.0 mg/kg (estimated value) and 14 mg/kg.

Rinseate Samples 10A Through 10C - PAHs were not detected in the rinseate samples greater than the method detection limits (0.05 $\mu\text{g/l}$ to 1.0 $\mu\text{g/l}$) from the Shelby Tube (10A and 10B) and the Van Veen (10C and 10C) samplers. Rinseate samples for PAHs were not collected for the Beta sampler.

TOTAL PETROLEUM HYDROCARBONS

A summary of the TPH (total petroleum hydrocarbon) results is presented in Table 3. The sediment samples from stations 1 and 3 through 9 were analyzed for TPH. Samples from station 2 were not analyzed for TPH.

Background Sampling Stations 9 and 8 - Total petroleum hydrocarbons were detected in the background Lake Washington sediment samples 9A and 9B at concentrations of 65 mg/kg and 13 mg/kg, respectively. The TPH concentrations detected in background Lake Union sediment samples 8B (120 mg/kg) and 8F (350 mg/kg) were approximately five to ten times the concentrations found in Lake Washington for generally similar sample intervals.

Sampling Stations 1, and 3 Through 7 - Total petroleum hydrocarbons were detected at concentrations between 39 mg/kg (5B) and 1,600 mg/kg (1A)

in the sediment samples from the Yard 1 Dry Dock facility. No general trends appear in the spatial distribution of TPH concentrations in the sediment samples.

Rinseate Samples 10A Through 10D - TPH was not detected in the rinseate samples greater than the method detection limits (1 mg/l) from the Shelby Tube (10A and 10B) and the Van Veen (10C and 10D) samplers. Rinseate samples for TPH were not collected from the Beta sampler.

POLYCHLORINATED BIPHENYLS

PCBs (polychlorinated biphenyls) were not detected above the detection limits in the background and the on-site sediments samples analyzed. A tentative identification was made for a PCB-like pattern in sample 1B (0.43 mg/kg), but a positive match could not be verified. PCBs were not detected in the Van Veen and Shelby Tube rinseate samples (10A through 10D) at concentrations greater than the detection limits (1.0 µg/l). Table 4 lists the method detection limits for PCB analyses in the sediment and rinseate water samples.

SUMMARY OF ANALYTICAL TESTING RESULTS--WATER SAMPLES

METALS

Beta Water Samples: Three water samples were collected with the horizontal Beta sampler within 1 foot of the bottom of Lake Union at sampling stations 8 (38.5-foot depth), and 2 (40.0 foot depth). Duplicate sample 12 (40.0-foot depth) was also collected at sampling station 2. Samples were submitted to the analytical laboratory for analysis of total metals, butyltin species, and hardness. Field water quality parameters (temperature, specific conductance, pH and dissolved oxygen) were measured in triplicate with field meters and the average of each set of field data was calculated. The analytical testing results and the field water quality results are summarized in Table 5.

Background Sample 8A - Zinc was detected in background water sample 8A at a concentration equal to the detection limit (0.01 mg/l [milligrams per liter]). Tributyltin was detected at a concentration of 9.2 ng/l (nanograms per liter) and hardness was measured at concentration of 42 mg/l as CaCO₃ (calcium carbonate). No other metals were detected in water sample 8A.

Sample 2A - Metals were not detected in water sample 2A at concentrations greater than the detection limits listed in Table 5. The

concentrations of the butyltin species detected in sample 2A were 4 ng/l DBT (dibutyltin), 4 ng/l TRBT (tetrabutyltin), 5 ng/l TBT (tributyltin) and 6 ng/l MBT (monobutyltin). Hardness was measured at a concentration of 40 mg/l as CaCO_3 .

Sample 12 (Duplicate 2A) - Lead and mercury were detected in water sample 12 at concentrations equal to the detection limits of 0.005 mg/l and 0.0005 mg/l, respectively. Zinc was detected at a concentration of 0.04 mg/l. The concentrations of the butyltin species detected in the water sample ranged from 21 ng/l MBT to 185 ng/l TBT. The higher metals concentration detected in sample 12, compared to 2A, may have been caused by disturbing the sediments at station 2 four days before collecting water sample 12. Hardness was measured at a concentration of 40 mg/l as CaCO_3 .

Beta Rinseate Samples 10E and 10F - Two Beta rinseate samples were collected prior to initial sampling attempts (10E) and during the field investigation (10F) to confirm decontamination procedures. The rinseate samples were analyzed for the constituents previously mentioned, including total metals and butyltin species. The testing results are summarized in Table 5.

Zinc was the only metal detected as a low level contaminant (0.02 mg/l) in Beta rinseate sample 10E. This may explain the low concentration of zinc detected in sample 8A. Butyltin species were not detected in sample 10E above the method detection limit (1.0 ng/l).

Metals were not detected in Beta rinseate sample 10F at concentrations greater than the detection limits listed in Table 5. MBT and DBT were detected at low concentrations of 15 ng/l and 4 ng/l, respectively. Sample 10F was collected after duplicate sample 12 was collected; therefore, the butyltin concentrations detected in 10F may reflect minor residual contamination from sample 12. The butyltin species concentrations measured in water sample 12 were much greater than the rinseate sample 10F results.

INTERSTITIAL WATER SAMPLES

Two sediment samples (2C and 8C) were centrifuged to separate the interstitial water from the sediment, and the water samples were analyzed for total metals and butyltin species. The sediment sample from 2C was also analyzed for butyltin species. The results are presented in Appendix C. The test results for the two water samples are summarized in Table 5.

Samples 2C and 8C - Arsenic, barium and the butyltin species were detected in the interstitial water samples removed from sediment sample 2C and background sediment sample 8C. Other metals were not detected in the interstitial water samples. Arsenic was detected in water sample 2C at a concentration of 0.898 mg/l, which is 20 times greater than the concentration detected in background sample 8C (0.042 mg/l). Barium was detected in samples 2C and 8C at generally similar concentrations of 0.19 mg/l (2C) and 0.16 mg/l (8C). The butyltin concentrations detected in 2C (27 ng/l MBT, 40 ng/l DBT, 22 ng/l TBT) are significantly less than the concentrations detected in background sample 8C (82 ng/l MBT, 90 ng/l DBT, 310 ng/l TBT). TRBT was not detected in sample 2C, while a concentration of 160 ng/l was detected in sample 8C.

SHELBY TUBE AND VAN VEEN EQUIPMENT BLANKS

Two field rinseate samples were collected prior to the initial sampling attempts (10A and 10C) and two were collected during the field study (10B and 10D) to confirm decontamination procedures. The rinseate samples were analyzed for the constituents previously mentioned, including total metals. The testing results are summarized in Table 5.

Shelby Tube Rinseate Samples 10A and 10B - Metals were not detected at concentrations greater than the detection limits (Table 5) in rinseate sample 10A, collected at station 9 prior to the start of sampling. Copper and lead were detected at low concentrations of 0.10 mg/l and 0.009 mg/l, respectively, in rinseate sample 10B, which was collected at station 7 prior to the start of sampling. These low level residual metal contaminants would not have noticeably affected the final sediment sample results.

Van Veen Rinseate Samples 10C and 10D - Barium, copper, lead and zinc were detected at low concentrations in Van Veen rinseate sample 10C, which was collected at station 9 prior to the start of sampling. Barium, copper and zinc were detected at concentrations slightly above the detection limits for each metal. The lead concentration detected in rinseate sample 10C (0.45 mg/l) suggests minor contamination resulting from spraying the rinseate water over the lead weights attached to the Van Veen. Lead contamination would not likely affect the samples because the weights do not come in direct contact with the sediment during collection. Lead was not

detected in rinseate sample 10D at concentration greater than the detection limits. Sample 10D was collected from the Van Veen sampler at station 7 prior to the start of sampling.

TCLP METAL RESULTS

Eleven sediment samples were tested by TCLP (toxicity characteristic leaching procedure) for metals to assist in evaluating the potential for upland disposal of these materials. This procedure is intended to mimic the potential generation of metals in leachate following disposal in a solid waste landfill. The TCLP testing results are summarized in Table 6.

GENERAL TCLP RESULTS

Selenium and silver were not detected in any of the TCLP extracts at concentrations greater than the detection limits. Mercury was detected only in sample 4A at a concentration equal to the detection limit (0.0005 mg/l). These results are representative of the relatively low concentrations of these metals in the sediment samples.

Arsenic: Arsenic was detected only in extracts 1A, 2A and 3A at concentrations between 0.05 mg/l to 0.17 mg/l. These arsenic concentrations are significantly less than the dangerous waste characterization criteria (5 mg/l) for TCLP extracts.

Barium: Barium was detected in the sample extracts (excluding background extracts) at concentrations between 0.060 mg/l and 0.33 mg/l. These barium concentrations are significantly less than the dangerous waste characterization criteria (100 mg/l) for TCLP extracts.

Cadmium: Cadmium was detected in the sample extracts (excluding background extracts) at concentrations between 0.011 mg/l to 0.050 mg/l. These cadmium concentrations are significantly less than the dangerous waste characterization criteria (1 mg/l) for TCLP extracts.

Chromium: Chromium was detected in four of the sample extracts (excluding background extracts) at concentrations between 0.005 mg/l to 0.012 mg/l. These chromium concentrations are significantly less than the dangerous waste characterization criteria (5 mg/l) for TCLP extracts.

Copper: Copper was detected in the sample extracts (excluding background extracts) at concentrations between 0.051 mg/l to 3.7 mg/l. There are no dangerous waste criteria for copper.

Lead: Lead was detected in the sample extracts (excluding background extracts) at concentrations between 0.28 mg/l to 3.0 mg/l. These lead concentrations are less than the dangerous waste characterization criteria (5 mg/l) for TCLP extracts.

Nickel: Nickel was detected in the sample extracts (excluding background extracts) at concentrations between 0.10 mg/l to 0.41 mg/l. There are no dangerous waste criteria for nickel.

Zinc: Zinc was detected in the sample extracts (excluding background results) at concentrations between 8.2 mg/l to 83 mg/l. There are no dangerous waste criteria for zinc.

REGULATORY SIGNIFICANCE OF WATER SAMPLES

The water quality data summarized in Table 5 were evaluated for environmental toxicity as regulated by the Water Quality Standards For Surface Waters of the State of Washington, WAC 173-201-010 through 173-201-120, 1988, and the U.S. EPA Quality Criteria For Water, 1986. Table 7 summarizes the fresh water quality regulatory standards for metals at 40 mg/l hardness; these standards are applicable to Beta water samples collected in Lake Union. Barium was not listed on the table because it is not regulated by the EPA and is not considered toxic in fresh water.

The metals concentrations detected in water samples 2A, 12 and 8A did not exceed the acute and chronic fresh water criteria in surface waters for arsenic, barium, cadmium, chromium, mercury, nickel, selenium and zinc. The lead concentration detected in water sample 12 (0.005 mg/l) did not exceed the acute fresh water criteria (0.025 mg/l), although it exceeded the chronic fresh water criteria (0.001 mg/l).

The detection limits specified in the final QA/QC plan for copper and silver (0.002 mg/l) were not performed by the laboratory because of a communications error in reporting the required detection limits to the laboratory. It was not possible to reanalyze the water samples because the samples were disposed of before this error was discovered.

The detection limit for silver (0.02 mg/l) is not less than the acute water quality standard (0.0008 mg/l). The silver concentrations detected in the sediments (less than 2.0 mg/kg to 4.2 mg/kg) suggest very low silver concentrations in the water samples.

The detection limit for copper (0.02 mg/l) is not less than the acute fresh water quality standard (0.0075 mg/l). We cannot estimate the water quality data for copper below the detection limits, although the survival rate of the bioassay analyses suggests very low copper concentrations.

The EPA developed provisional water quality criteria for TBT in 1987 at concentrations of 531 ng/l acute and 47 ng/l chronic to protect aquatic life; however, the EPA set an advisory criterion at 10 ng/l chronic. The concentrations of TBT detected in the three water samples (5 ng/l [2A] to 185 ng/l [12]) did not exceed the acute criteria; however, the results from sample 12 exceeded the chronic criteria.

A comparison of the results for Beta water samples (2A, 12, 8A) and interstitial water samples (2C and 8C) shows significantly greater arsenic and barium concentrations in the interstitial water samples and also a copper concentration (0.03 mg/l) greater than the detection limit in 8C. The copper concentration detected exceeds the acute criteria and the TBT concentration exceeds the chronic criteria in interstitial background water sample 8C. The arsenic concentration detected in 2C exceeds the acute criteria and the TBT concentration detected exceeds the advisory chronic criteria. The comparison also shows the TBT concentration is significantly greater in the background interstitial water sample than in the on-site interstitial water sample.

REGULATORY SIGNIFICANCE OF THE SEDIMENT SAMPLES

The sediment quality data presented in Tables 1 through 4 were evaluated for environmental toxicity associated with various remedial alternatives, including the no-action alternative, dredging the contaminated sediment, and capping the contaminated sediment with clean material. The sediment quality results were not evaluated in this report for environmental toxicity under the Final Sediment Management Standards, April 1991, Chapter 173-204 WAC developed by Ecology (Washington State Department of Ecology). These recently adopted sediment standards were developed for marine sediments, although Ecology has reserved the option to apply these regulations to fresh water sediments on a case-by-case basis. It would be not be appropriate to evaluate the fresh water sediments in Lake Union by these regulations for this phase of the investigation. The environmental toxicity of the sediments was evaluated for dredging and disposal as specified in the PSDDA (Puget Sound Dredge Disposal Analysis) Reports

Management Plan (June 1988) and the Evaluation Procedures (September 1989) developed by the U.S. Army Corps of Engineers, Washington State Department of Natural Resources, the U.S. EPA Region X and Ecology.

NO-ACTION ALTERNATIVE

A no-action alternative would allow the contaminated sediment to remain in place and would limit the disturbance of in-place sediments in Lake Union. An overall evaluation of the sediment quality shows that the types and concentrations of chemical contaminants present in the on-site bottom sediments and in background Lake Union samples have had possible adverse effects on biological activity in the Lake Union bottom sediments. Based on the bioassay results, there appears to be a significant difference between the mortality rate of the benthic organisms in the Yard 1 sediments compared to the Lake Union and Lake Washington background samples. There appears to be a relatively direct correlation between the overall concentrations of contaminants present in the Yard 1 sediments and the mortality rates of the benthic organisms, although the water quality data at the bottom of Lake Union did not show any short term acute toxic effects to the bioassay organisms as demonstrated in the water bioassay tests.

The exact nature of the chemical or chemicals that have the greatest adverse effects on the benthic organisms have not been determined as part of this study.

Environmental Significance of No-Action Alternative: The no-action alternative was evaluated to demonstrate the environmental significance associated with either performing no action or by performing alternative remedial options (dredging or capping). The acceptance of the no-action alternative as a remedial option may produce the following negative impacts and positive consequences to the Lake Union and the environment.

The negative impacts to Lake Union resulting from accepting a no-action alternative program generally would be caused by the physical presence of the contaminated bottom sediments. The negative impacts include the following: (1) the contaminated bottom sediments were demonstrated to be toxic to benthic organisms; (2) the chemical constituents in the sediments potentially may be bioaccumulated and possibly biomagnified (increasingly greater concentrations of the chemicals) up through the food chain to

ultimate human consumption; and (3) the potential exists for the slow release of the constituents into the Lake Union water as dissolved compounds at concentrations near or below practical analytical quantification limits.

The positive consequences to accepting the no-action alternative include the following: 1) the potential environmental consequences associated with disturbing the sediments during dredging or during capping operations would not occur; 2) the environmental consequences associated with physically removing (treating contaminated water), containing and transporting contaminated sediment and processing the contaminated sediment for disposal would not occur; 3) the sediments appear to pose negligible environmental risk to the lake water quality because no short-term acute toxic effects were demonstrated in the water bioassay; and 4) the depth of water for operations and navigation purposes would be maintained.

As demonstrated by the water sampling at station 12 (where the water column was slightly affected [elevated butyltin species concentrations] by sediment disturbances 4 days prior to collecting the water sample), disturbances of the sediment may introduce a temporary pulse of suspended or dissolved chemical constituents into the lake bottom water. Dredging or capping activities may potentially disturb the sediments even if appropriate measures are taken to limit dispersion of the sediments (using a silt curtain) during remedial activities. A rapid pulse of suspended and dissolved chemical constituents may introduce a potentially lethal dose of chemical constituents into Lake Union, which may cause a short-term to possibly longer-term degradation of the water quality during remedial actions. A release of a contaminant plume may affect the Lake Union ecosystem to an unknown extent for an unspecified (suspected short-term) period of time. Capping the bottom sediment would reduce the available free board space for continuing operations at the Yard 1 facility. Natural sedimentation, in comparison, is expected to slowly cover the contaminated sediment in time, which would accomplish the same goal as capping and may be worth the environmental risk in the short term. There is no guarantee that a sediment cap would not be damaged, removed or recontaminated through contact with the contaminated material over time, thus negating the remedial alternative.

DREDGE DISPOSAL ANALYSIS

The sediment quality results (chemical and biological) were evaluated according to the guidelines specified in the PSDDA dredge material evaluation procedures. The chemical data were directly compared to the screening levels and the maximum levels presented in PSDDA Table A-7 "Screening Level (SL) and Maximum Level (ML) Guideline Chemistry Values," updated February 20, 1990 (Appendix E).

According to PSDDA, open-water disposal of dredge spoils with contaminant concentrations greater than the SLs and MLs are acceptable only in the presence of favorable bioassay results. The SLs and MLs are used as guidance for determining when bioassay testing is required.

A general ranking system was developed by PSDDA for the various navigated waterways in Puget Sound as a guide for planning proposed dredge activities. Lake Union was given a high ranking for the potential presence of chemicals of concern in the PSDDA guidelines. Selection of the required number of chemical and biological samples for PSDDA evaluation was based on the ranking system, historical data and estimated dredge quantities.

Unconfined Open-Water Disposal: Unconfined open-water disposal involves placing dredge spoils in an unconfined setting where the spoils are not isolated or separated from the environment. Unconfined disposal provides numerous potential pathways for chemicals entrained in the sediments to be released into the environment during the disposal activities.

The primary goal of the dredge disposal analysis is to determine if dredge spoils are suitable for unconfined open-water disposal. The suitability of dredge disposal is based on demonstrated ecological or human health effects, as developed in the PSDDA guidelines. Dredge spoils with contaminant concentrations greater than maximum level standards are potentially unacceptable for unconfined disposal. A brief comparison of the chemical results, presented below, demonstrates that unconfined open-water disposal may be unacceptable according to PSDDA guidelines. The results are evaluated for the Yard 1 facility, including sampling stations 1 through 7, shallow and deep intervals.

Metals - Arsenic concentrations detected generally exceeded the 57 mg/kg SL (screening level) in the sediment samples on-site and exceeded the 700 mg/kg ML (maximum level) at sampling stations 1, 2, and 4.

Cadmium concentrations detected exceeded the 0.96 mg/kg SL in sediment samples from all sampling stations and exceeded the 9.6 mg/kg ML in samples from stations 2, 4, 5, 6 and 7.

Copper concentrations detected exceeded the 81 mg/kg SL in sediment samples from all sampling stations and exceeded the 810 mg/kg ML in sampling stations 1, 2, 4 and 6.

Lead concentrations detected exceeded the 66 mg/kg SL in sediment samples from all sampling stations and exceeded the 660 mg/kg ML in sampling stations 1, 2 and 4.

Mercury concentrations detected exceeded the 0.21 mg/kg SL in the sediment samples from stations 1, 2, 4, 5 and 6. The ML for mercury was not exceeded in any of the samples.

The SL for nickel was not exceeded in any of the samples collected.

The silver concentrations detected exceeded the 1.2 mg/kg SL in sediment samples from stations 1, 2, 3 and 4. The ML for silver was not exceeded in any of the samples.

Zinc concentrations detected exceeded the 160 mg/kg SL in sediment samples from all sampling stations and equaled or exceeded the 1,600 mg/kg ML in sediment samples from stations 1, 2, 4, 5 and 6.

The tributyltin concentration detected in sediment sample 2C (0.19 mg/kg) exceeded the (0.03 mg/kg) SL. TBT was analyzed in only one sediment sample.

PAHs - The calculated total LPAH concentrations detected exceeded the 0.6 mg/kg SL and the 6.1 mg/kg ML in all the sediment samples. Generally, the greatest LPAH concentrations were observed at stations 4, 6 and 7. The lowest LPAH concentrations were observed at stations 1, 2, 3 and 5.

The calculated total HPAH concentrations detected exceeded the 1.8 mg/kg SL in all the sediment samples and the 51 mg/kg ML in the sediment samples from all sampling stations except station 3A. Generally, the greatest HPAH concentrations were observed at sampling stations 4 through 7 and background station 8. The lowest LPAH concentrations were observed at sampling stations 1 through 3.

Miscellaneous Compounds - The concentrations detected for dibenzofuran and bis(2-ethylhexyl)phthalate generally exceeded the SL and ML for those samples where these compound were detected at concentrations greater than the method detection limits.

PCBs - PCBs were not detected in the sediments at concentrations greater than the detection limits and generally not exceeding the SL and ML criteria, although the detection limits at sampling station 6 were greater than the regulatory guidelines because of matrix interferences.

Confined Disposal: Confined aquatic disposal is the placement of contaminated dredge spoils in a suitable (and approved) deep water disposal site after which the disposal material is capped with clean materials. The primary goal of capping is to isolate the contaminated spoils from the environment, thereby effectively eliminating the potential for subsequent adverse environmental effects. No approved confined disposal sites presently exist.

Confined aquatic disposal is an option that would require further, detailed evaluation to determine the suitability of this option. This option may be more costly than alternative disposal methods.

Upland Disposal: Upland disposal involves placing contaminated dredge spoils within an environmentally acceptable disposal site. Upland disposal options include nearshore disposal within a diked structure, disposal in a permitted solid waste landfill and disposal in a hazardous waste landfill.

Nearshore disposal involves placing the dredge material within an engineered sediment retention structure that allows the interstitial water to drain from the sediments before the contaminated material is capped with a clean soil cover. The contaminated materials placed in the disposal site would potentially release contaminated interstitial water into the environment at levels that may exceed regulatory guidelines. Collection and treatment of the interstitial water would be required to minimize environmental impacts and comply with regulatory standards. Ongoing environmental monitoring may also be required at the disposal location to evaluate the environmental consequences of nearshore disposal.

Upland disposal in a solid waste landfill would require transporting the contaminated dredge material to a permitted solid waste disposal facility. No processing would be done on the material except for reducing the moisture content to acceptable standards prior to disposal. Landfill disposal may be possible when the material is not characterized as a dangerous waste and when the landfill is willing to accept the waste.

The TCLP test results for metals show that the contaminated sediment (as dredge spoils) would not be classified as a dangerous waste. However, the HPAH data for the Yard 1 sediments result in PAH concentrations that are close to the dangerous waste designation levels.

The main environmental risk associated with landfill disposal is the possibility of future environmental liability. These materials may be determined to be toxic by future regulatory standards and may require responsible parties to assist in potential remedial activities at the landfill. To reduce the risk of this future liability, the material could be transported to a permitted hazardous waste landfill at a substantially greater cost.

Environmental Significance of Dredging: The environmental significance of dredging the contaminated sediments from the Yard 1 facility was evaluated to provide a basis for demonstrating the negative and positive effects to the water quality and ecosystem of Lake Union.

The negative effects or impacts of dredging are as follows: (1) dredging activities would cause disturbances of the contaminated sediments, which may potentially affect the lake water quality to an unknown extent; (2) dredging would require that the large quantities of contaminated water be collected, contained and treated prior to disposal; (3) the dredge sediments may require chemical treatment or stabilization before confined disposal is permitted, (these processes may generate additional waste volumes and waste streams); (4) dredging would require that an environmentally suitable confined disposal site (subaqueous or upland location) be determine or designed (at substantially greater costs); (5) dewatering of the dredge sediments during disposal may produce chemical alterations (chemical oxidation or dissolution) of the dredge materials, which may result in further environmental risks at the disposal location; (6) confined disposal of the dredge material will not reduce the overall toxicity of the material; (7) dredging would require temporary storage, loading, transporting and unloading of the contaminated sediments, which may result in additional risks to the environment; (8) long-term environmental monitoring may be required at the disposal site to define potential environmental impacts associated with the confined disposal alternative.

The positive effects of dredging include the following: (1) removal of the contaminated sediments will reduce the potential for adversely affecting

the water quality of Lake Union and should promote the natural reestablishment of the bottom-dwelling aquatic organisms to Lake Union; (2) dredging will reduce the need for further studies once the ecosystem has returned to normal; (3) dredging will increase the navigable depths of water at the Yard 1 facility.

IN-PLACE CAPPING

In-place capping is a process by which relatively clean sediment is placed over the contaminated sediment, effectively isolating the contaminated material from the environment. The clean sediment cap also provides a suitable environment for benthic organisms to reestablish viable populations. In-place capping is considered a remedial technology, although the toxicity of the material is not reduced by this process.

Capping as an option at the Yard 1 Dry Dock facility may involve placing approximately 4 to 10 feet or more of a suitable capping material over the contaminated sediment. A 10-foot thick cap would reduce the average water depth at the Yard 1 facility to 30 feet. Figure 19 shows depth of water contours compiled from information supplied by UNIMAR and field measurements of water depth measured in January 1991 by GeoEngineers. A specific design of the cap would require a detailed evaluation of construction procedures, capping materials and probable burrowing depths of benthic organisms.

Environmental Significance of In-Place Capping: In-place capping of the contaminated sediments at the Yard 1 facility was evaluated for environmental significance to demonstrate the negative and positive effects on the water quality and ecosystem of Lake Union. In-place capping may be an environmentally acceptable option if the actual process does not adversely affect the environment and if the cap provides a permanent containment system (will not be degraded, damaged, removed or eroded over time by natural processes or human activity) for the contaminated material.

The negative environmental impacts of capping include releasing interstitial pore water into the surrounding lake water during consolidation of the sediments and dispersion of the fine-grained contaminated sediments into surrounding areas during placement of the cap material. Capping will reduce the navigable water depth and may impede operations and activities at the Yard 1 facility. Capping may not provide a completely permanent remedial option because ongoing natural processes (such as burrowing

organisms) or human activities may degrade or breach the cap material. Capping will require ongoing environmental monitoring (additional cost expenditures) to evaluate the effectiveness of the cap material and to document reestablishment of the benthic community in the lake bottom ecosystem.

The positive aspect of capping is the benefit of isolating the contaminated sediments from the lake ecosystem without the potential adverse environmental risks and impacts that may result from dredge removal. Capping may be performed relatively easily with reduced capital expenditures~~x~~ compared to dredging and disposal. Capping should effectively isolate the contaminated sediments from the lake water and should provide a suitable habitat for the reestablishment of the benthic organisms. Capping, if proven to be effective, may provide the advantages of isolating the contaminated sediments, providing a new habitat for benthic organisms and satisfying environmental risk concerns.

CONCLUSIONS

As presented in FishPro's report, the water quality at the bottom of Lake Union did not show any short-term acute toxic effects to bioassay organisms as demonstrated in the water bioassay tests with nearly 100 percent survival. The concentrations of chemical constituents present in sediments at the Yard 1 Dry Dock Facility (stations 1 through 7) had a significant impact on the bioassay organisms as demonstrated by the high mortality rates observed in the bioassay analyses. The sediments in the bottom of Lake Union (station 8), were demonstrated to be more toxic to bioassay organisms than the sediments from Lake Washington (station 9). The concentrations of chemical constituents in the Yard 1 Facility sediment generally exceed the PSDDA SL and ML guideline chemistry values and were demonstrated to be toxic to the bioassay organisms, which demonstrates that unconfined open water disposal may be unacceptable according to PSDDA guidelines. The data presented in the bioassay report may suggest that a no action alternative is unacceptable, but the environmental significance of no-action may be appropriate upon further considerations of the environmental impacts associated with remedial actions such as capping or dredging.

Generally, the concentrations of chemicals present in the sediments exceed the PSDDA guidelines for unconfined open-water disposal. Dredging

of the contaminated sediments is a possible viable remedial option, provided that suitable dredging procedures are used and approved confined disposal site becomes available.

Confined disposal of dredged sediments would have to be evaluated in greater detail to determine the suitability of this option. This option may be more technically demanding than other disposal options.

Nearshore disposal of bottom sediments may be an environmentally acceptable option if a suitable disposal site can win the approval of appropriate regulatory agencies. Considerable design effort would be needed to develop an appropriate plan for confined nearshore disposal of dredged sediments.

Upland disposal appears to be a viable disposal option, provided that the sediments can be permitted for disposal in a solid waste landfill. Significant efforts would be needed to dewater the dredge spoils prior to transporting the material to a solid waste landfill.

Capping may be an appropriate alternative provided that the environmental effects associated with constructing the cap are minimized or reduced to acceptable levels.

We do not feel it is appropriate at this time to recommend one remedial option over another. A thorough evaluation of the one or two best remedial options may be completed when the legal issues regarding the nature and extent of the contamination at the Yard 1 facility are resolved.

LIMITATIONS

This report has been prepared for use by United Marine International, Inc. in an investigation of the bottom sediment and water at the Yard 1 Dry Dock Facility in Seattle, Washington. The report is not intended for use by others and the information contained herein may not be applicable to other sites.

Our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No other conditions, expressed or implied, should be understood.

- o o o -

If you have any questions concerning this report, please call.

Respectfully submitted,

GeoEngineers, Inc.

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N. Northlake Way

Offices and
Shops

Existing
Shoreline

Property
Line

LAKE
UNION

EXPLANATION:

1⊙ SEDIMENT SAMPLING STATION

— 1.0 — SAND BLASTING MATERIAL
THICKNESS CONTOUR (FEET)

0 100 200
SCALE IN FEET

REFERENCE:

UNTITLED DRAWING PROVIDED BY MARINE POWER & EQUIPMENT, INC.,
DATED 1-12-86.

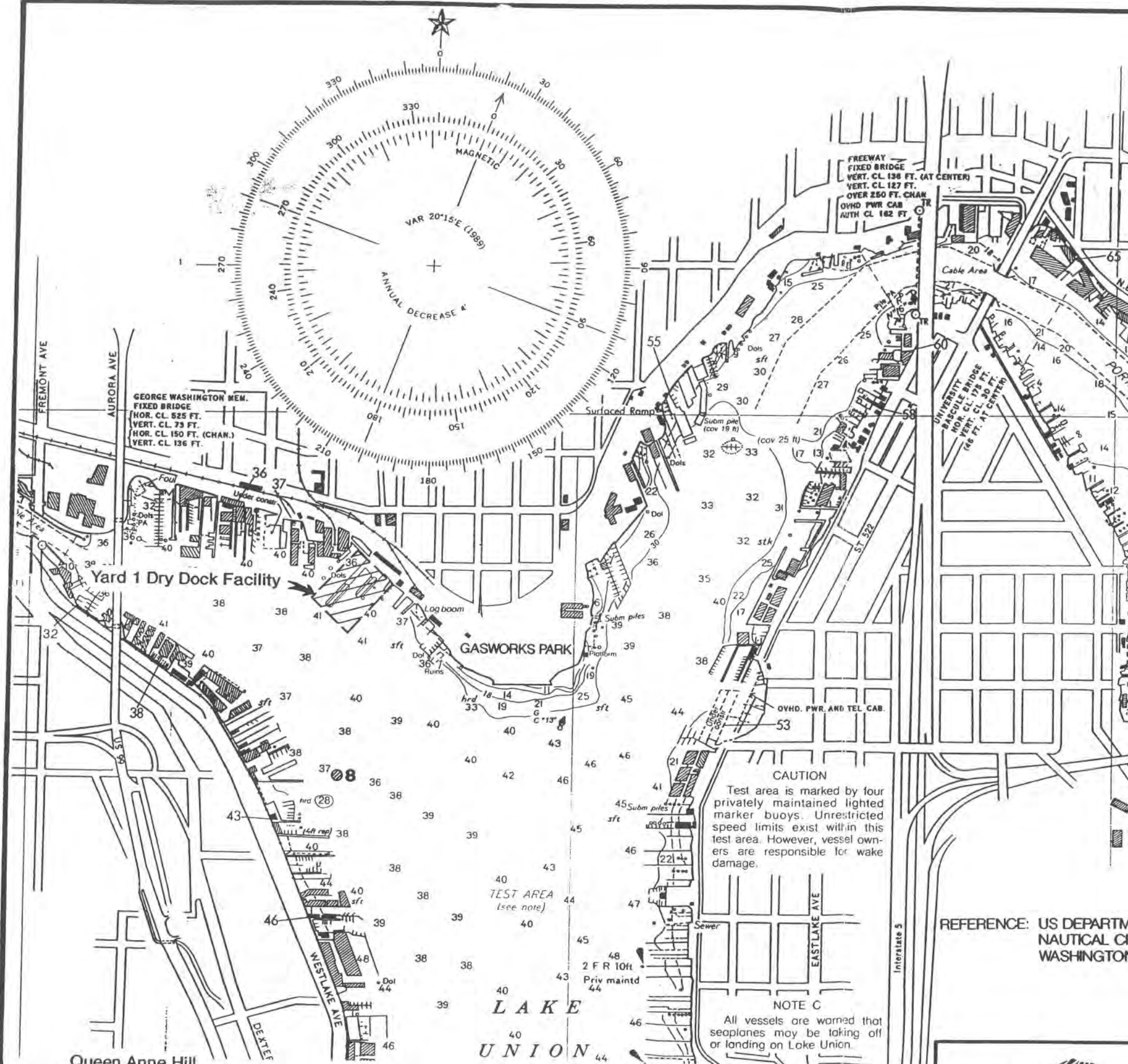
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SAND BLASTING MATERIAL THICKNESS MAP

FIGURE 2

6-26-91 ZJD
7-23-91 RRR

1299-003-804 REJ:JSD 7/19/91 (D)



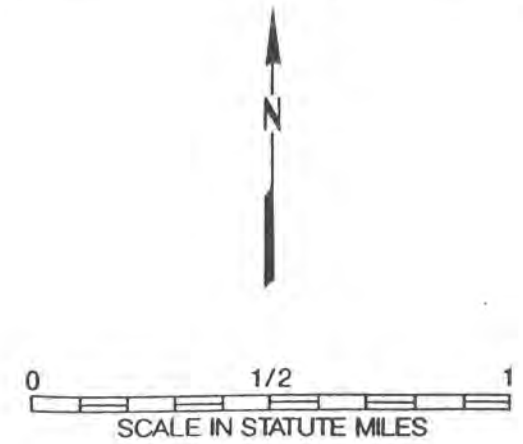
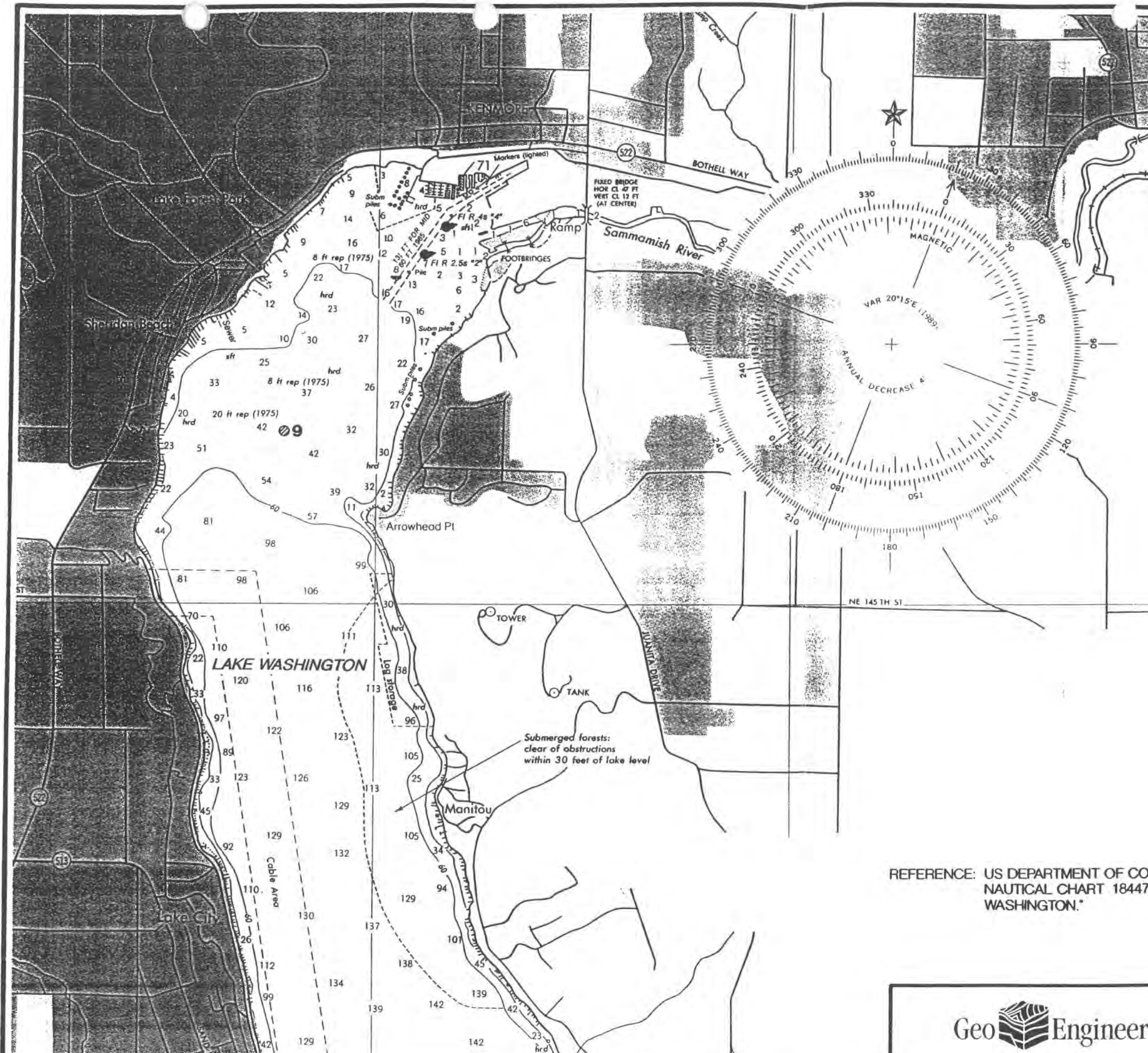
EXPLANATION:
 8 BACKGROUND SAMPLING STATION LOCATION AND NUMBER

REFERENCE: US DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NAUTICAL CHART 18447, ENTITLED "LAKE WASHINGTON SHIP CANAL AND LAKE WASHINGTON, WASHINGTON."

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BACKGROUND SAMPLING STATION 8

FIGURE 3



EXPLANATION:
 9 BACKGROUND SAMPLING STATION LOCATION AND NUMBER

REFERENCE: US DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NAUTICAL CHART 18447, ENTITLED "LAKE WASHINGTON SHIP CANAL AND LAKE WASHINGTON, WASHINGTON."

1299-003-804 7/19/14 DTJ:JW 448-6621